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THE STD-2 DROBYSEV TOPOGRAPHIC STEREOMETER

AND REVISION OF PHOTOGRAMMETRICALLY

DETERMINED RELIEF ON A

1:10,000 SCALE MAP

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- CZECHOSLOVAKIA -

U. S. JOINT PUBLICATIONS RESEARCH SERVICE

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-Czechoslovakia-

Proposal for substituting the field check of photogrammetri-
cally prepared topographic maps of 1: 10,000 scale with a photo-
grammetric method using the STD-2 Drobysev topographic stereometer.
I. The contemporary method of checking topographic maps prepared by
the photogrammetric method.

Topographic maps on a 1: 10,000 and 1: 5,000 scale, prepared
by the photogrammetric method, are currently inspected in the CSSR
at the time of the topographic field check. The accuracy of photo-
grammetrically determined topography by and large satisfies the
prescribed criteria. As a result, it is mainly the evaluated relief
which is the subject of topographic checking.

Ideally it is assumed that the quality of all photogrammetric
evaluations done heretofore and the increasing experience of the
evaluators will make it possible to carry out the checking of photo-
grammetric evaluations rather in the form of spot checks than by
the method and to the extent employed to-date.

The contemporary method of topographic field checking consider-
ably lengthens the manufacturing cycle of a map and considerably
reduces the economic efficiency of the photogrammetric method. For
that reason, the Central Administration for Geodetics and Cartography
announced that the problem of checking photogrammetrically prepared

topographic maps is the number one task for 1957-58 for improvers and inventors in the field of geodetics and cartography.

II. Proposal for a new Method of Checking Photogrammetric Relief Determinations.

It was suggested to the author of this article that he solve the problem by making a comparison of the elevations of a larger number of points which were determined on universal machines by both the geodetic and photogrammetric methods.

A second independent photogrammetric relief determination of the map sheets, or else an independent photogrammetric elevation of a larger number of conveniently located points on photographic picture pairs could be a sufficient check on photogrammetric determinations. The photogrammetric method of checking would be faster and more economical than the heretofore employed method of topographic field checks. However, the extent of the planned assignments for the /available/ universal machines does not allow their employment for systematic checking.

I suppose that for this work one could use topographic stereometers which, as far as they are employed in photogrammetric operations, are not fully utilized. Topographic stereometers serve in the differentiation method for determining elevations on picture pairs, i.e., for preparing that part of a topographic map which is the prime object of checking following the photogrammetric determination of topographic maps.

The proposal for using topographic stereometers for checking a photogrammetrically evaluated relief is based on the following facts or assumptions:

1. In the Soviet Union where the accuracy criteria for representing relief on topographic maps of 1: 10,000 scale are basically the same as in the CSSR, the majority of mapping work utilizes the differentiation method, in which relief evaluation is carried out on topographic stereometers.

2. N. A. Sokolova-viz. (1) page 12 - states that the median error for relief evaluation on a topographic stereometer made from a picture pair with a camera of fixed f = 210 mm is $\pm$ 0.03 mm on the horizontal paralax and with constant f = 100 mm it is $\pm$ 0.04 mm. The author further states on page 34 of the same treatise on the subject of analyzing the accuracy of point-by-point relief determination on a stereometer and stereo-planigraph, that when using pictures on a 1:7,500 scale made with a camera of fixed f = 210 mm, the elevations of the individual points on the topographic stereometer were determined with a median error of $m \Delta p$ = $\pm$ 0.017 mm.

3. Even if the accuracy of evaluations on universal machines is greater than on topographic stereometers, it is possible (on the actual basis of height determination of individual points on a stereometer with a median error of $m \Delta p$ = $\pm$ 0.025 mm) to verify on a topographic stereometer of the proper accuracy whether the relief

evaluated on universal machines is in line with the accuracy criterion for elevation reproduction.

When using shots on a 1:14,000 scale made with a camera with fixed f = 210 mm, the median horizontal paralax error of $m_{\Delta p}=\pm$ 0.025 mm corresponds to a median relief error of $m_h = \pm$ 0.95 m. This value is smaller than 1/2 of the allowable deviation Δ [delta] $= \pm$ 2.0 m for a terrain slope of 5% and up.

For pictures on a 1:18,000 scale, made with a camera having fixed f = 115 mm, the central relief error in the horizontal paralax of $m_{\Delta p} = \pm$ 0.025 mm. corresponds to a median elevation error of $m_h = \pm$ 0.72 m. This value is smaller than one half of the allowable deviation $\Delta = \pm$ 1.5 m for a terrain slope as low as 0 to 5%.

4. After evaluation on a universal machine, it is comparatively easy to determine from the evaluation record of picture pairs the necessary elements for evaluation on a stereometer, which when done by the well-known differentiation method is quite expensive in terms of the time needed.

For evaluation on a stereometer, it is necessary to know the lengthwise slope angles φ_L and φ_P, the difference of the crosswise slope angles of the shots Δ w, the height of the airplane above Hv, the base point for relief evaluation, and the photographic base on the scale corresponding to the height of flight Hv.

a) The lengthwise slopes φ and differences of the crosswise inclinations Δ w have to be known according to (2) page 155 with the accuracy indicated in Table 1.

Table 1

in mm.	Allowable Deviations in Minutes	
	φ	$\Delta \omega$
100	5	7
200	7	11

The mutual angles of inclination $\Delta \varphi$ and Δw after orientation of picture pairs on universal machines of the first order are determined with a median error of approximately $\pm$ 2'.

When calculating the elements β and ξ_0 for evaluation on a stereometer one must take into consideration the different meanings of counting the degrees of lengthwise and crosswise inclinations on a Zeiss stereo-planigraph and a Wilde autograph.

If for the evaluation a Zeiss stereo planigraph was used, then

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$$\beta' = \frac{d \cdot 3438}{h \cdot 6366} (\varphi_P - \varphi_L)$$

$$\text{and} \quad \varrho'_0 = \frac{r \cdot 3438}{h \cdot 6366} (\omega_P - \omega_L)$$

After evaluation on a Wilde autograph

$$\beta' = \frac{d \cdot 3438}{h \cdot 6366} (\varphi_P - \varphi_L) \& \varrho'_0 = \frac{r \cdot 3438}{h \cdot 6366} (\omega_P - \omega_L).$$

where D = 100 mm and r = 86 mm.

where d = 100 mm
and r = 86 mm.

The values β and ϱ are calculated from the relative lengthwise and crosswise inclinations of the pictures. The record of how the relative and absolute orientation was carried out must therefore be treated with such attention that, especially after evaluation on a Zeiss stereo planigraph, the actual lengthwise relative inclination of the pictures is taken into the calculation of value β.

Checking the setting of angle β on a topographic stereometer can be done only if in the picture pair a central elevation point is determined.

b) For evaluation on a topographic stereometer, the allowable photographic altitude deviation dH must not, according to (2) page 182, exceed the value given by sample equation

$$dH = \frac{H}{h} dh$$

where dh denotes the allowable deviation of elevation determination.

For the picture scales under consideration, and on the assumption that dh should be set at a median error of ± 0.5 m, it is necessary to know the altitude of the airplane with the accuracy shown in Table 2.

	Constant camera focus, in mm.	Scale of the shot 1 : m,	For excess height, in meters	
			50	100
Table 2			Required altitude accuracy of plane, dH, in meters	
	210	1 : 13 000	27	13
	115	1 : 18 000	20	10

After carrying out the absolute orientation on a universal machine of the first order, the height of the flight is determined to approximately 0.3 0/00 H. The altitude of the flight above sea level for

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the left picture H_{OL} and the flight altitude above zero for the right picture H_{OP} is determined from values on a Z column. This is done for the left main point z_{HL} for the right main point z_{HP} and for the appurtenant elevations above sea level h_{HL} and h_{HP} according to sample equations

$$H_{OL} = h_{HL} + m'(z_{HL} + b_{z_L}) \text{ and}$$
$$H_{OP} = h_{HP} + m'(z_{HP} + b_{z_P})$$

where m' signifies the scale number of the model. The elevation of the flight above the point of departure for evaluating the left picture is determined according to $H_{UL} = H_{OL} - h_v$ and similarly for the right picture $H_{up} = H_{op} - h_v$.

c) The allowable deviation for determining the basic scale for photographing the point of departure b_v again must not, according (2) page 194, exceed the value given by sample equation

$$db_v = \frac{b_v}{h} \, dh,$$

i.e., if b_v = 72 mm and dh = $\mp$ 0.5 m for h = 50 m, the value of $\mp$ 0.70 mm.

After carrying out the absolute orientation on a universal machine of the first order, the distance of the main points b' in the evaluating scale must be given with an accuracy of approximately $\mp$ 0.2 mm. From the measured distance of the main points b' on the tracing of the relief points on map scale 1: M, the base line for photographing b after evaluation on a Zeiss stereo-planigraph is determined by the sample equation

$$b = b' + \frac{H_{OL} + H_{OP}}{2 \cdot 6366 \cdot M} (\varphi_L - \varphi_P)$$

and after determination on the Wilde autograph according to sample equation

$$b = b' - \frac{H_d + H_{OP}}{2 \cdot 6366 \cdot M} (\varphi_L - \varphi_P)$$

For evaluation on a stereometer, it is, however, necessary to know the basic photographic scale corresponding to the height of the flight above the point of departure. For evaluation on the right picture, this is given by the sample equation

$$b_v = b, \frac{f \, M}{H_{VP}}$$

and for evaluation on the left picture

$$b_v = b \frac{f M}{H_{VL}}$$

For correctly determining the necessary elements for stereo-metric evaluations from the operational records of the relative and absolute orientation on universal machines, it is basic to know

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the zero values of the individual scales on the universal machines as well as on the stereometer.

III. Proposed Working Procedure for the Use of a Topographic Stereometer for Checking a Photogrammetrically Determined Relief.

When using a topographic stereometer for checking relief determinations, the procedure is as follows:

1) Check the settings of zero values of all scales on universal machines and stereometers.

2) When making stereoscopic examinations and before evaluation on universal machines, mark on the positive copy of every picture pair on survey paper a number of points which in essence would determine the skeleton of the terrain. If possible, select such points for the territorial skeleton as would be the object of positional evaluation on the universal machine.

3) After carrying out the relative and absolute orientation, enter in the evaluational record the values of all scales. From these values and from the values obtained after evaluation on the universal machine, calculate the necessary elements for evaluation on a stereometer.

4) After evaluation of the isohypses on the universal machine, determine the elevations of the marking points on the terrain skeleton and, unless these are the object of positional evaluation, mark also their position on the transparency of the elevation points.

5) From the given orientation points and necessary elements determined from the universal machine evaluations, determine on the topographic stereometer the elevations of the terrain skeleton points which were marked out on the pictures as under point 2) above.

6) Compare the elevation points determined from the measurement of the individual points on the stereometer with the points determined on the universal machine, or with the values determined by interpolation of the isohypses.

7) If the comparative results do not exceed the allowable deviations for altitude representation on topographic maps of scale 1: 10,000, assume the altitude evaluation to be suitable. In cases of large differences, after exchange of pictures in the stereometer carriers and after using another orientation point as a point of departure from the evaluation, repeat the evaluation on the stereometer and, according to the result, decide whether it is necessary to check once more the evaluation of the picture pair on a universal machine.

8) In cases where a repeated evaluation on a universal machine was necessary, comparison of results from the first universal machine evaluation with the evaluation results on the topographic stereometer will make it possible to decide which evaluation is correct. It is likely that only occasional and unimportant instances will occur which would make it necessary to undertake a field check.

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IV. Assumed Advantages of Checking with a Topographic Stereometer.

1) The suggested method of photogrammetric checking anticipates the use of machines which are available and are not being used for the fulfillment of planned tasks.

2) To carry out the suggested photogrammetric check of a map-sheet of a forest-free territory, only about one half to one quarter of the necessary norm hours for photogrammetric evaluation are necessary. This would afford a considerable time saving as compared with the time needed by the currently used method of checking.

3) On the basis of statistical data concerning the quality of the evaluation of a large number of picture pairs, it would be possible to weigh the necessity and extent of checking photogrammetric determinations. It would also be possible to determine objectively the qualitative rank of the individual evaluators, which would increase their desire to do highest quality work on each picture pair.

4) To determine the elevations of individual points on topographic stereometers, it would be necessary to train within 1 to 2 months new workers which would be better suited for work with universal machines.

V. Results of the Practical Verification of the Proposed Method.

The proposal to use the Drobysev topographic stereometer STD-2 for checking photogrammetrically determined relief on a 1: 10,000 scale map was accepted by the contest jury of the USGK /Ustredni Sprava Geodezie a Kartografie — Central Administration for Geodetics and Cartography/ as a solution to study task number 1 announced as a contest among improvers and inventors for the year 1957-58. It was handed over to the Geodetic and Topographic Institute of Prague for verification.

Engineer J. Sima was entrusted with carrying out the test. He used the suggested method on two 1: 10,000 scale maps, evaluated on universal machines from photos of an approximate scale of 1: 14,000. The pictures for one of the map sheets were made on a camera with fixed f = 210 mm and for the second map sheet with a camera with fixed f = 115 mm.

For evaluation, copies of the flight picture were used on photographic survey paper. Within the space of the map sheet for which pictures of the f = 210 mm camera were used, 7 picture pairs were checked. On the map sheet evaluated on the Wilde A5 autograph from pictures with the f = 115 mm camera, 11 picture pairs were checked, whereby 30 to 40 control points were marked on the surface of each picture pair. In the report which was submitted for judging to the technological department of USGK and to the technical inspection department of USGK the elevations marked on the topographic stereometer were compared with the elevations determined on the Zeiss stereoplanigraph and on the Wilde A5 autograph. The latter were assumed to be correct.

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Table 3

Groups of deviations according to order of magnitude

Terrain Slope in %	Allowable deviation from elevation in meters	Median evaluation error	to 1 m.		1—1.5 m		1.5—2 m		2—3 m		over 3 m	
			n	%	n	%	n	%	n	%	n	%
		For Evaluation by Stereoplanigraph										
		For Stereometer										
5—10	±2,0	±1,1±0,1	35	67	12	23	4	8			1	2
		±0,9±0,1	39	67	12	21	5	9	2	3		
10—20	±2,5	±1,0±0,1	21	67	6	20	4	13				
		±1,1±0,1	17	57	8	27	3	10	2	6		
5—20		±1,0±0,1	55	67	18	22	8	10			1	1
		±1,0±0,1	56	64	20	23	8	9	4	4		

Table 4

Groups of deviations according to order of magnitude

Terrain Slope in %	Allowable deviation from elevation in meters	Median evaluation error	to 1 m		1—1,5 m		1,5—2 m		2—3 m		over 3 m	
			n	%	n	%	n	%	n	%	n	%
		For evaluation by autograph										
		For stereometer										
0—5	±1,5	±0,5±0,0	104	95	3	3	2	2				
		±0,6±0,1	94	86	11	10	4	4				
5—10	±2,0	±0,7±0,1	47	84	7	13			1	3		
		±0,9±0,1	37	69	11	20	3	6	2	5		
0—10		±0,6±0,0	151	92	10	6	2	1	1	1		
		±0,7±0,1	131	81	22	14	7	4	2	1		

The technological department of USGK, the technical inspection department of USGK and the technical inspection department of GTU [Geodeticky a Topograficky Ustav -- Geodetic and Topographic Institute] checked the elevations of 93 points within the space of 5 picture pairs of the map sheet which was made up from pictures on the photo-camera with fixed f = 210 mm. It also checked the elevations of 171 points within the space of 7 picture pairs on the map sheet which was made with a camera with a fixed f = 115 mm. For 5 of the 12 checked picture pairs, the central control point was measured. 7 picture pairs were evaluated from only 4 control points. The Tacheometrically measured elevations were compared with values determined on universal machines, as well as on a topographic stereometer, so that the effectiveness of checking with a stereometer could be better and more reliably judged.

The review results of the USGK technical inspection did not fully confirm the previously assumed accuracy of determining altitudes with a topographic stereometer. It was the opinion of the technical inspection team that the reason for this may have resided in the lack of experience with evaluations on a topographic stereometer.

In the case of the pictures made with the f = 210 mm camera it was judged that the stereometer could probably only be used for finding occasional gross mistakes in the determinations. It was recommended that further tests for verifying the usefulness of the proposed solution include comparisons of the elevations of points interpolated from the relief by means of the universal method, while the altitudes are determined tacheometrically on a stereometer.

In the case of pictures taken on the f = 115 mm camera the possible use of the topographic stereometer for relief checking of the photogrammetric determination is admissible on condition that the reason for the wrong determination of one of the picture pairs is determined.

In order to determine the reasons for some unexpectedly large evaluation deviations on a topographic stereometer, Engineer J. Sima repeated the evaluation of some of the picture pairs by using a procedure which checked also several values taken over from the relative and absolute orientation record of a universal machine.

1) The elements for mutual orientation were numerically determined on a stereo-comparator on the basis of the measured vertical paralaxes. It became apparent that several values of the scale after orientation on a universal machine were incorrectly recorded.

2) The lengths of the photographic base lines were measured on a stereo-comparator, corrected for the longitudinal angle of inclination, and reduced according to the height of the airplane above the point of departure. The wrong calculation of the photographic base lines from values determined with the universal method

was the one that exerted the greatest influence on the result of
the first evaluation on a stereometer. This happened especially
with picture pairs taken from great heights.

3) The determined altitudes were checked by means of double
evaluation on a stereometer and, in the second case, after inter-
change of the pictures on the stereometer carrier and after using
another control point as point of departure for the evaluation. The
photographic base line and remaining evaluation elements were recal-
culated with regard to the new point of departure.

After completion of the calculations, the altitudes determined
with the stereometer were compared with altitudes determined on
universal machines and with altitudes determined tacheometrically.

If we assume the directly measured altitudes to be correct,
then the accuracy of photogrammetric height determination on a
universal machine of the first order and on a stereometer, when taken
from pictures of 1: 14,000 scale made in a f_k = 210 camera, is expres-
sed in Table 3. Pictures on the same scale taken with an f_k = 114 mm
camera are shown in Table 4.

In his conclusion of the report regarding experimental work with
a topographic stereometer for checking the relief of a photogrammet-
rically prepared 1: 10,000 scale map, comrade Engineer J. Sima is
of the opinion that the basic assumption of the proposed method is
realistic that elevations of well identified points in forest-tree
territory can be determined with a median error of $\pm$ 0.025 mm in
the horizontal paralax.

This opinion is also confirmed by the experiences of the
geodetic Institute in Bratislava where the initiative of comrade
Engineer J. Hagary initiated the practical application of the pro-
posed method already before completion of experimental work in the
geodetic and topographic Institute of Prague.

The lecture was presented by Professor Engineer Dr. J. Klo-
boucek, CVUT (Ceske Vysoke Uceni Technicke - Advanced Czech Insti-
tue of Technical Studies), Prague.

References:

1. Sokolova, N. A. "Certain Problems of Aerophotographic
Computation in Medium and Large Scales." Trudy TsNIIGAK
(Works of the Central Scientific Research Institute of
Geodesy, Aerial Surveying and Cartography), Issue 89.

2. Gercenova, K. N., Aceret'ko, A. K., Posobiye po foto-
gram-metricheskim rabotam (Textbook of Photogrammetry),
Moscow 1956.

Lecturer's Comments:

Like all field measurement work the field revision of topogra-
phic maps made by means of photogrammetric methods, which now is the
practice in our country, is costly. It is known that the measurement

of control points as well as topographic field checks constitute the highest percentage of mapping costs, while the simple photogrammetric evaluation on a universal machine is comparatively cheap. It is therefore necessary to continue to look for appropriate ways and means leading to a speed-up and further cheapening of aerial topographic mapping. For determining control points, this country successfully uses aero-triangulation methods, analytical aero-triangulation and, lately, also measurement with a tellurometer. However, topographic field revision is still expensive because it is often very extensive. In foreign countries more care is taken sometimes with universal machine evaluation so that topographic field checking is greatly lessened and sometimes even omitted. This is the method which will in the future be used in this country also. For it one has to have aerial pictures of high quality, taken on good aerial film, as well as reliable and well trained evaluators working on universal machines. Aerial surveying films are already considerably better than they used to be, so that now more care will have to be taken with the selection and training of evaluators who would have to work reliably on universal machines. In turn, their unusually demanding special work will have to be correctly evaluated /i.e., paid/.

Engineer Pichlik suggests in his article that the topographic field revision of photogrammetrically made maps be replaced by laboratory checks made on a topographic stereometer. This specifically means a second photogrammetric altitude evaluation of a certain number of points by use of photogrammetric apparatus of the third order. The proposed method has certain advantages, but also certain disadvantages. For testing, it uses the same photogrammetric material which was used for the evaluation. This, if anything, makes it worse because as a rule original negatives are surveyed on universal machines, whereas on stereometers photographic paper copies are surveyed, either glued on glass or placed on photographic paper with a metal liner. The survey has all the disadvantages known to the differentiation method. The orientation of pictures on a stereometer cannot simply be carried out according to data obtained from measurements on a stereo-planigraph. The positional part of the map cannot be checked by this method and, as far as altitude checking is concerned, it can by and large only restrict itself to the less accurate second photogrammetric height determination of individual, well-identified positional points on a map and on a stereometer. To check the interrelation of terrain features by this method and to find incorrect reproductions by means of contour lines of altitudes and depressions (which is always a definite weakness of photogrammetric determination) is also not too feasible. On those parts of the map where the layout cannot be well identified, the comparison of point elevations as determined by a stereometer on the one hand, and with point elevations as determined by contour

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line interpolations on the other hand, is rather unreliable because the identification of the points is not well assured. Too extensive checking with a stereometer cannot be done. This method brings to light only a few rough errors which should not even appear in a careful evaluation on a universal machine. Since the original evaluation was carried out on a machine of the first order, while the stereometer is a machine of the third order, generally less accurate, it may happen that larger deviations appear in stereometer checking of elevations, and that it then becomes necessary to carry out still another stereometer evaluation after having exchanged the pictures in their carriers, and finally, in some cases, to do a new evaluation on a stereo-planigraph. However, just because the same photogrammetric bases were used in all cases, the check thus carried out is not necessarily reliable. The check results of the USGK technical inspection did not at first confirm to the fullest extent the originally assumed accuracy of elevation determinations by means of topographic stereometers. All in all, one can, however, agree with the opinion that the elevation determination of well-identified points in unforested territory can be done with a median error in the horizontal paralax of $\pm$ 0.025 mm. For the given case this means an accuracy of elevation determinations of well identified points of $\pm$ 1 m. However, work with a stereometer demands a good and well trained worker. In Bratislava, another photogrammetric apparatus (a stereotop) proved to be better than a stereometer when used for similar purposes. Some institutes have used the stereometer to a limited extent only, while other institutes or photogrammetric units do not use the stereometer for these purposes and don't even intend to introduce its use. Keeping extensive and costly topographic field checks to a minimum is necessary, however, and the best way to achieve this will be an improved evaluation on universal machines as well as good selection and training of evaluators before they begin to work on their own. Convenient, and at the same time simple, checks will have to be worked out for the universal machine evaluation of every picture pair in order to reduce to a minimum the often still necessary topographic field revision. Experience to date, however, seems to indicate that an adequate topographic field revision is sometimes unavoidable.

Signed: Prof. Engineer Dr. J. Kloboucek

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